Dermal Exposure Assessment

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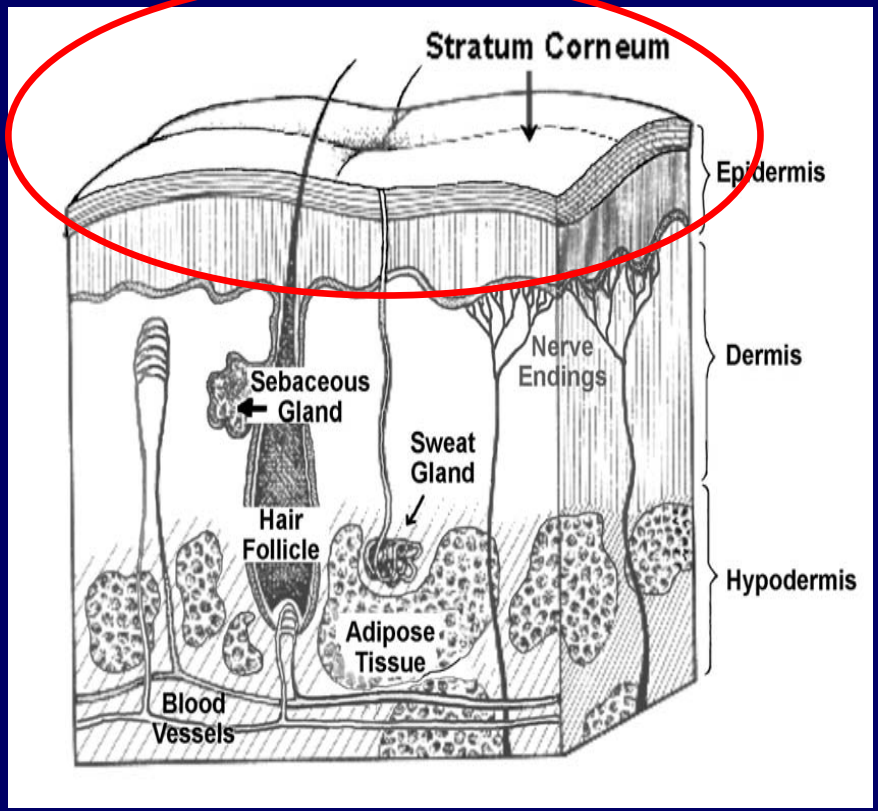
What is the Role of the Skin?

- Critical barrier for
  - Preventing microbial invasion
  - Water balance
  - Temperature control

Key Barrier: Stratum Corneum

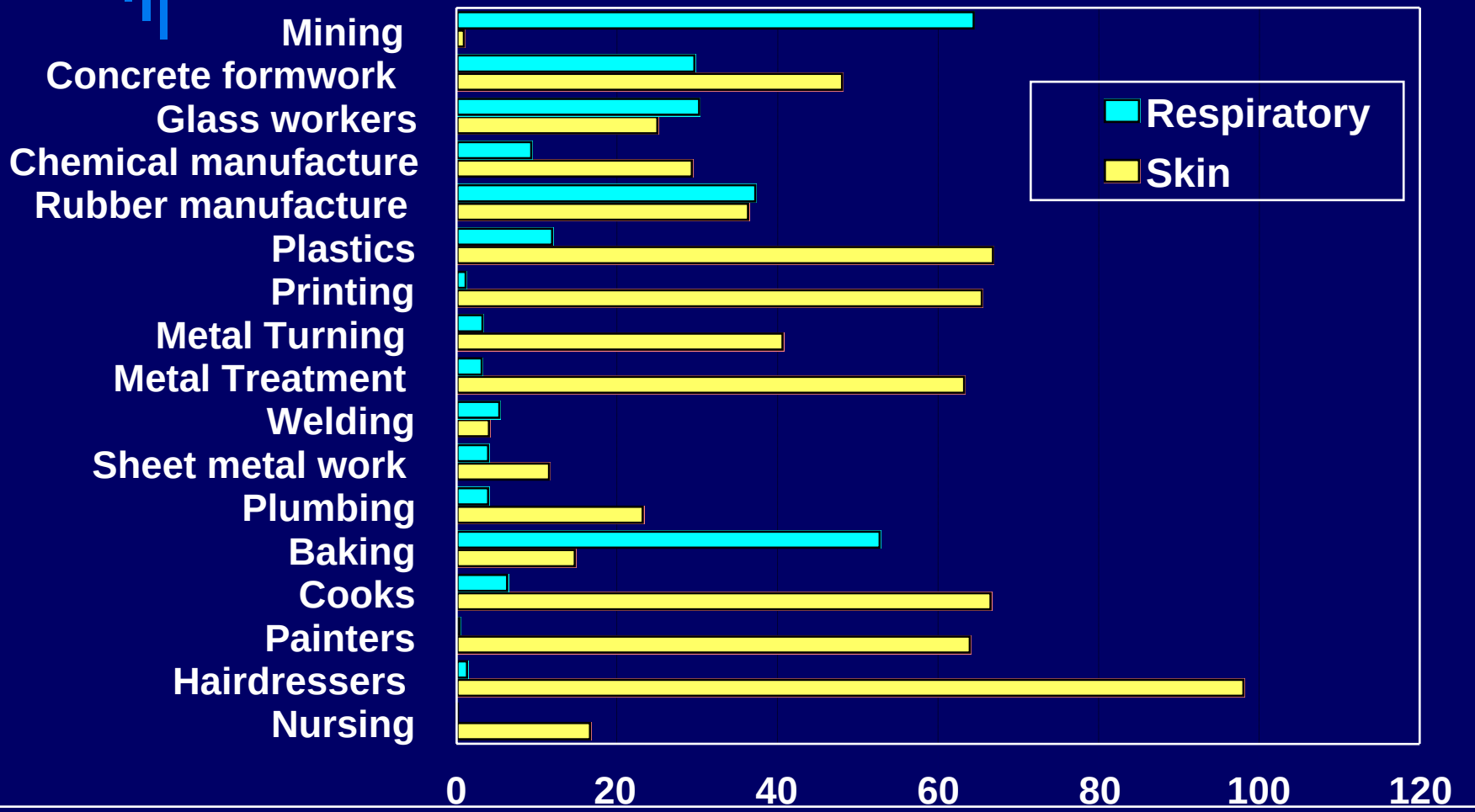


- Comprised of dead flattened cells
- Only ~15 μm thick on most of the body
- In comparison, the typical human hair is 50-70 μm thick and 3M Scotch© tape is 25 μm thick
- Palms and soles thicker, ~600 μm

Effects of Dermal Exposures

- Direct effects on skin
  - Mechanical
  - Irritant
  - Allergic
- Systemic toxicity
- Infectious agents
- Systemic sensitization

Incidence of Reported Occupational Illness in FRG Requiring Change of Loss of Occupation by Occupation (cases/100,000)



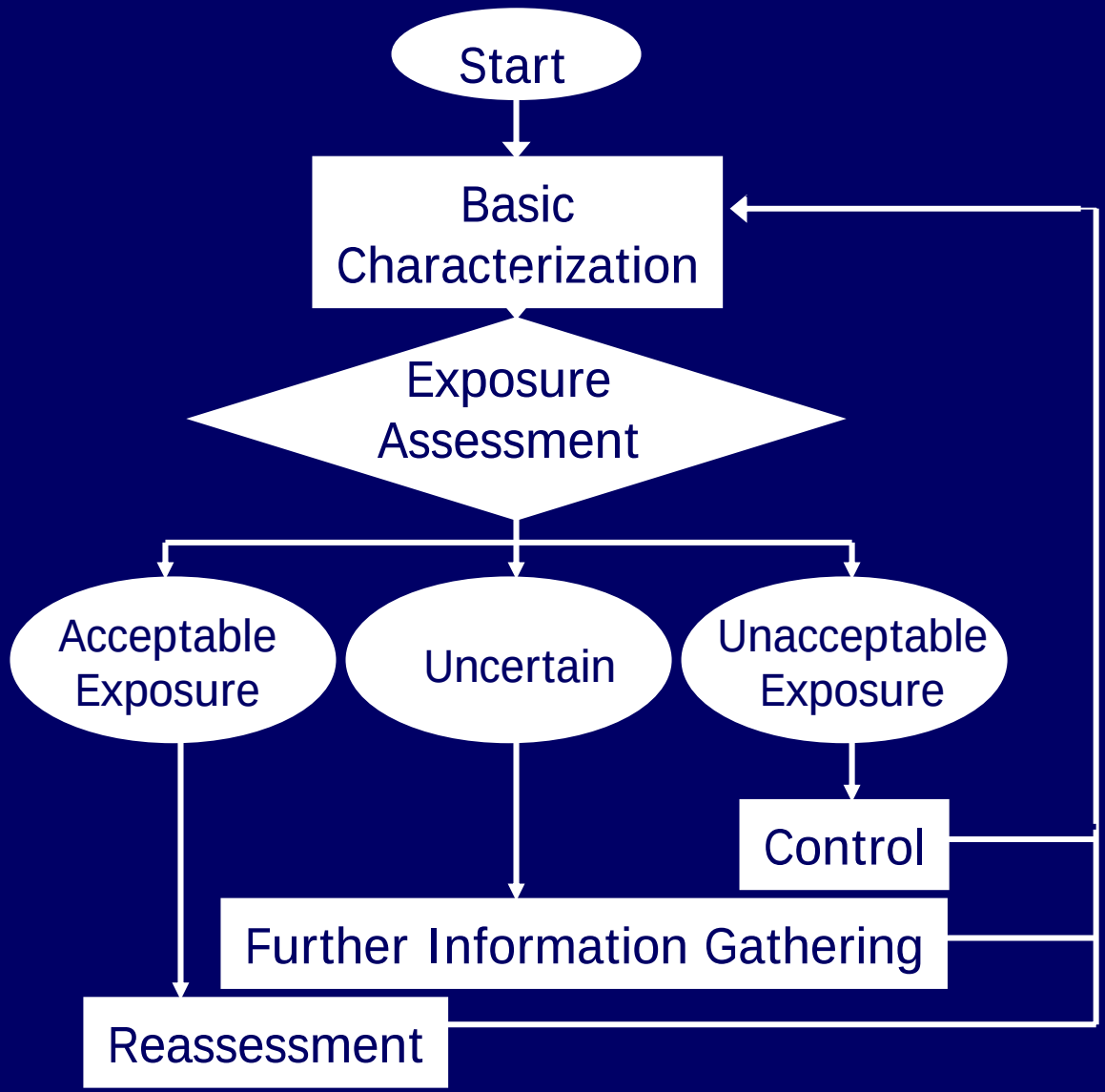
Barriers to Conducting Dermal Exposure Assessments

- Lack of understanding about exposure hazards by workers and/or safety and health professionals
- Knowledge gaps still exist for dermal exposure assessment methodologies
- Dermal exposure assessment regulations often lack specifics or include unclear requirements

Reasons to Conduct Dermal Exposure Assessments

- OSHA expects and requires it
- There is a lot of great information available to help in assessing dermal exposures
- The comprehensive exposure assessment picture for your employees is very incomplete without it
- What you don't know may be hurting your employees

AIHA Strategy to Assess and Manage Workplace Exposures



Mulhausen JR and Damiano, J, eds. A Strategy for Assessing and Managing Occupational Exposures, 2nd ed. Fairfax, VA: AIHA Press, 1998. Appendix II: Dermal Exposure Assessments.

A Recommended Strategy for Dermal Exposure/Risk Assessments

- Basic characterization of dermal hazards
- Initial dermal exposure assessment and grouping of worker activities
- Exposure acceptability determination
- Control of unacceptable exposures, further information gathering if undetermined, reassessment of acceptable exposures

Step 1: Basic Characterization

- Dermal hazard identification and toxicity assessment
  - Identify agents of concern by reviewing process flow diagrams, ingredients, MSDSs, and professional practice guidelines
  - Evaluate other available hazard data
  - Determine if OSHA, NIOSH, AIHA, or ACGIH has set a Skin Notation, an inhalation OEL, BEI®, or BEEL

Example – MSDS for n-hexane

http://msds.pdc.cornell.edu/msdssrch.asp

Section 3 - Hazards Identification, Including Emergency Overview
HEXANE (N-HEXANE) (AMSCO SOLV 1487)

Health Hazards Acute & Chronic: MAY BE AN EYE IRRITANT. MAY CAUSE SKIN IRRITATION UPON PROLONGED OR REPEATED CONTACT. RESPIRATORY TRACT IRRITATION. CENTRAL NERVOUS SYSTEM DEPRESSION IN HIGH CONCENTRATIONS. WEAKENING AND NUMBNESS IN EXTREMITIES.

Signs & Symptoms of Overexposure:
N/K

Medical Conditions Aggravated by Exposure:
N/K

Route of Entry Indicators:
Inhalation: YES
Skin: YES
Ingestion: YES

Other Sources of Toxicity Information

- SRC's TSCATS Database
  - http://www.syrres.com/esc/tscats.htm
- NIOSH skin topic page
  - http://www.cdc.gov/niosh/topics/skin/
- PubMed searches – free NIH archive
  - http://www.pubmedcentral.nih.gov
- EPA Guidance

EPA Dermal Guidance Documents

- Dermal Exposure Assessment Principles (2002)
  - http://www.epa.gov/nceawww1/pdfs/derexp.pdf
- Exposure Factors Handbook (1997)
  - Body surface area studies and activity exposure factor analyses
  - http://cfpub.epa.gov/ncea/cfm/exposfac.cfm?ActType=default
- Risk Characterization Handbook (2000)
  - Overview of risk characterization-related products
  - http://epa.gov/osp/spc/rchandbk.pdf

Step 2:
Initial Exposure Assessment

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Step 2: Initial Exposure Assessment

- Worker activities and SEG determination
  - Observe work practices and interaction with substances of concern
  - Do workers have direct contact with dermal hazards via bare skin or gloved hands? Is splashing a risk?
  - Do work practices differ between groups of workers or individual workers?

Step 2: Initial Exposure Assessment

- Worker activities and SEG determination
  - How are tools shared in the workplace? How are tools cleaned/disinfected?
  - What is the level of workplace housekeeping?
  - What are the environmental conditions in each work area?
  - How frequently do workers wash hands?

Step 2: Initial Exposure Assessment

- Worker activities and SEG determination
  - Characterize the following five key factors:
    - Dermal contact area on skin surface
    - Dermal concentration transferred to the skin
    - Dermal contact frequency and time of total contact with the skin
    - Dermal retention time on skin following exposure
    - Dermal penetration potential through skin

Dermal Contact Area

- Dermal contact is the total area of likely skin contact if the agent of concern is a systemic toxic
- Skin area is not as significant if the agent is a local toxic/skin toxic/allergen
- Assume no PPE used when estimating
- Are one or two hands used? Is the whole hand affected, or perhaps only the palm?

Skin Surface Areas

Taken from the U.S. EPA's Exposure Factors Handbook, Volume I, Chapter 6: Dermal, Table 6-4, Surface Area by Body Part for Adults, m^2

Body Part	**Mean (Men)**	**5th to 95th Percentile**
Head	1180 cm^2	900-1610 cm^2
Arms	2280 cm^2	1090-2920 cm^2
Forearms	1140 cm^2	945-1360 cm^2
Hands	840 cm^2	596-1130 cm^2
Palms	150 cm^2	
Thumb	~24 cm^2	

Dermal Concentration

- Total concentration by weight of the agent of concern on the skin surface area (can be difficult to estimate)
- For local irritants, concentration will affect severity of reaction and future reactions
- For allergens, concentration will affect the rate of sensitization of the exposed population
- For systemic toxics, concentration will affect penetration rate through the skin

Dermal Contact Frequency

- Dermal Contact Frequency
  - The frequency of contacts or the percentage of the total work shift that the agent of concern comes in contact with the skin
- Consider the length of the task relative to the length of the work shift and the number of repeated contacts with skin

Dermal Retention Time

- Dermal retention time
  - Likelihood that the agent of concern will remain on the skin following exposure contact (for both systemic or local toxics)
- Consider factors such as vapor pressure and particulate characteristics that would make an agent more likely to remain on skin over time

Dermal Penetration Potential

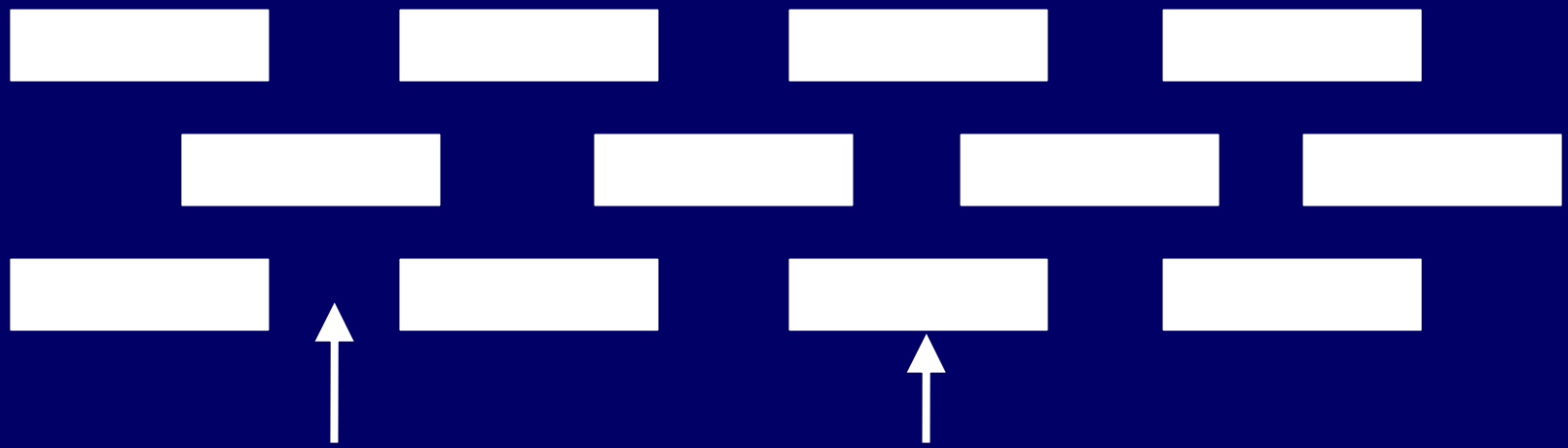
- Dermal penetration potential
  - The mass of actual penetration into the body through both the stratum corneum and the dermis (for systemic toxics)
- Comparatively, dermal absorption is
  - Penetration into or through the stratum corneum ONLY (not necessarily available for systemic absorption)

Dermal Penetration Potential

- Factors affecting dermal penetration or absorption include
  - Octanol-water partition coefficient (Log Ko/w)
  - Contamination of clothing or other covering
  - Kp values (permeability coefficient)
  - Skin washing frequency
  - Skin temperature under gloves

Dermal Penetration: The Bricks and Mortar Model

- Multiple pathways for permeation
  - Fat-soluble (lipophilic) chemicals
  - Water-soluble (hydrophilic) chemicals



Factors Affecting Skin Penetration

- The health or condition of the skin at the time of exposure is very important
- Skin can be damaged in many ways by chemicals or the environment (humidity, temp)
- Physical damage includes scratches, cuts, exposure to cold temperatures
- Chemical damage includes partial or full removal of the stratum corneum or its lipid base

Assessing Skin Penetration Potential Using “Skin” Notations

- OSHA, NIOSH, and ACGIH have all defined “skin notations” for certain chemical substances
- NIOSH is in the process of developing a new, more detailed skin notation
- Purely qualitative
- Of 30,000 chemicals in commercial use, only about 275 have a “skin” notation; many dermal hazards may not carry the notation

Skin Notations

- Examples of the ACGIH TLV skin notations

Substance	TWA	STEL/C	Notations	Mol Wgt	TLV Basis
Acrylamide	0.03 mg/m^3	-	Skin; A3	71.08	CNS; dermatitis
N-Hexane	50 ppm	-	Skin; BEI	86.18	Neuropathy, CNS; irritation

Step 3: Screening-Level Exposure Acceptability Determination

- Are exposures acceptable, unacceptable, or undetermined?

- The use of a qualitative rating scheme specific to dermal exposures may be helpful

Dermal Hazard Rating

Rating	Description
1	Reversible or very low skin or systemic toxicity
2	Moderate but reversible skin or systemic toxicity
3	Irreversible/chronic skin or systemic toxicity or sensitization
4	Life threatening skin or systemic toxicity or sensitization

Dermal Contact Area

- Assume the absence of PPE for contact rating

Rating	Description
1	Unexpected/unlikely
2	Very small area of skin contact
3	Contact possible to hands and forearms
4	Contact possible to significant area of skin

Dermal Concentration or Loading

- Assume absence of PPE for concentration rating

Rating	Description
1	Negligible concentration of agent likely to contact the skin
2	Low concentration of agent likely to contact the skin
3	Moderate concentration of agent likely to contact the skin
4	High concentration of agent likely to contact the skin

Dermal Contact Frequency

Rating	Description
1	Minimal contact with skin; one or two incidental contacts; contact during less than 5% of work shift
2	Up to 10 incidental contacts with skin; contact during less than 10% of work shift
3	Up to 50 incidental contacts with skin; contact during less than 50% of work shift
4	Routine incidental contact with skin throughout shift; contact during 50-100% of work shift

Dermal Retention Time

Rating	Description
1	Amount transferred unlikely to remain on skin for any period of time (i.e., high volatility, dry and powdery)
2	Amount transferred may remain on skin for some time (i.e., some volatility or adherence to skin)
3	Amount transferred is likely to remain on skin for a significant period of time (i.e., low volatility, high MW, sticky or consolidated on skin even if not visible)
4	Amount transferred very likely to remain on skin (i.e., substance not volatile, MW > 100, substance very likely to stick to skin)

Dermal Penetration Potential

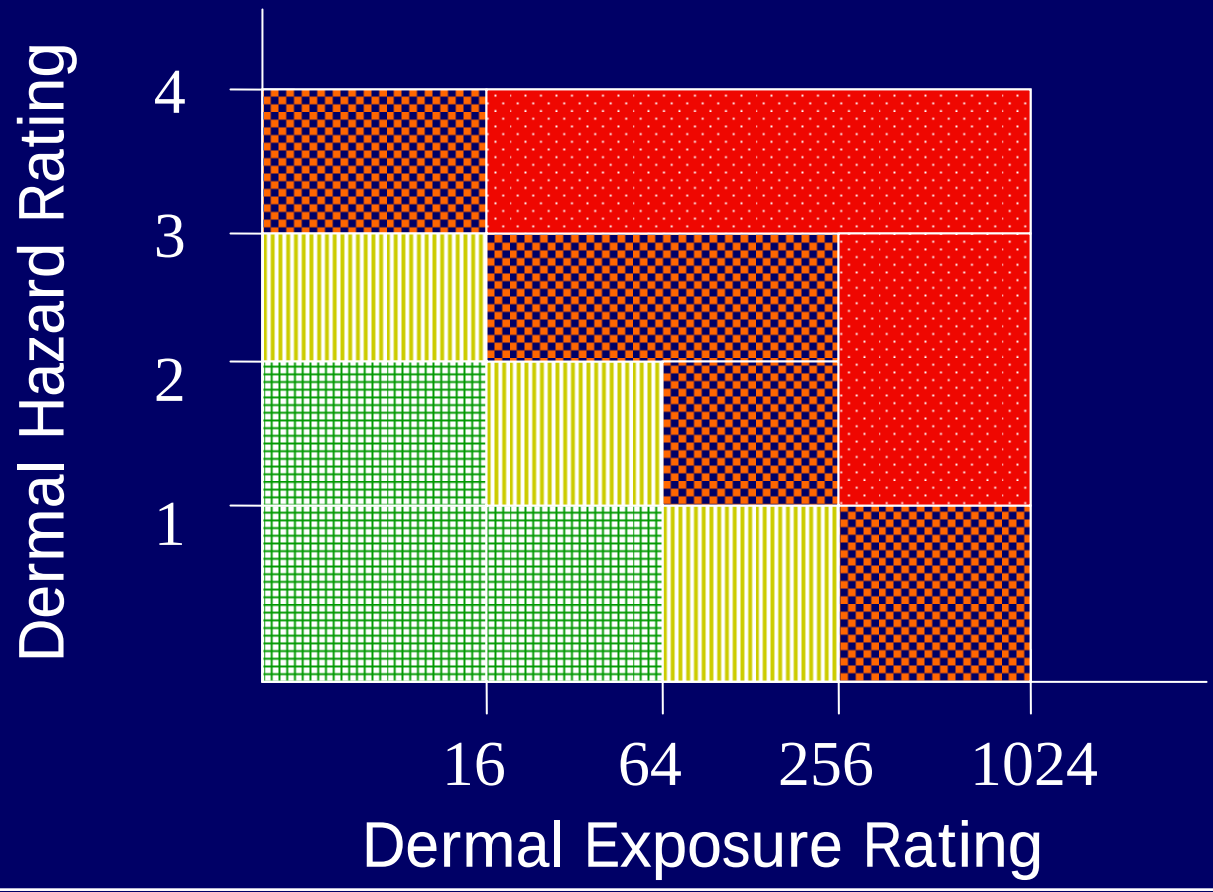
Rating	Description
1	Rare (large, insoluble particles)
2	Less likely (small insoluble particle > 1 micron in size, or both poor lipid solubility and poor water solubility)
3	Possible or slow (very small insoluble particles < 1 micron, or some lipid solubility and some water solubility, or marginal skin health)
4	Probable or likely (good lipid solubility and good water solubility, or poor skin health)

Qualitative Dermal Assessment

- Exposure Rating = Contact Area * Concentration * Contact Frequency * Retention Time * Penetration Potential

  ER = CA * C * CF * RT * PP
- Exp. Rating from 1 to 1024
- Exp. Rating with Hazard Rating yields the priority rating
- Use the following chart to determine low, medium, high, very high priority

Qualitative Assessment of Dermal Exposures



Example: Qualitative Assessment

Determine:

- Dermal hazard rating
- Dermal contact area
- Dermal concentration
- Dermal retention time
- Dermal penetration potential

...for this employee, who works as a brake repair mechanic, using a hexane-based brake cleaner (30% n-hexane)

Make a Qualitative Estimate

- Dermal hazard rating: 3
- Dermal contact area: 3
- Dermal concentration: 3
- Dermal exposure time: 4
- Dermal retention time: 2
- Dermal penetration: 4

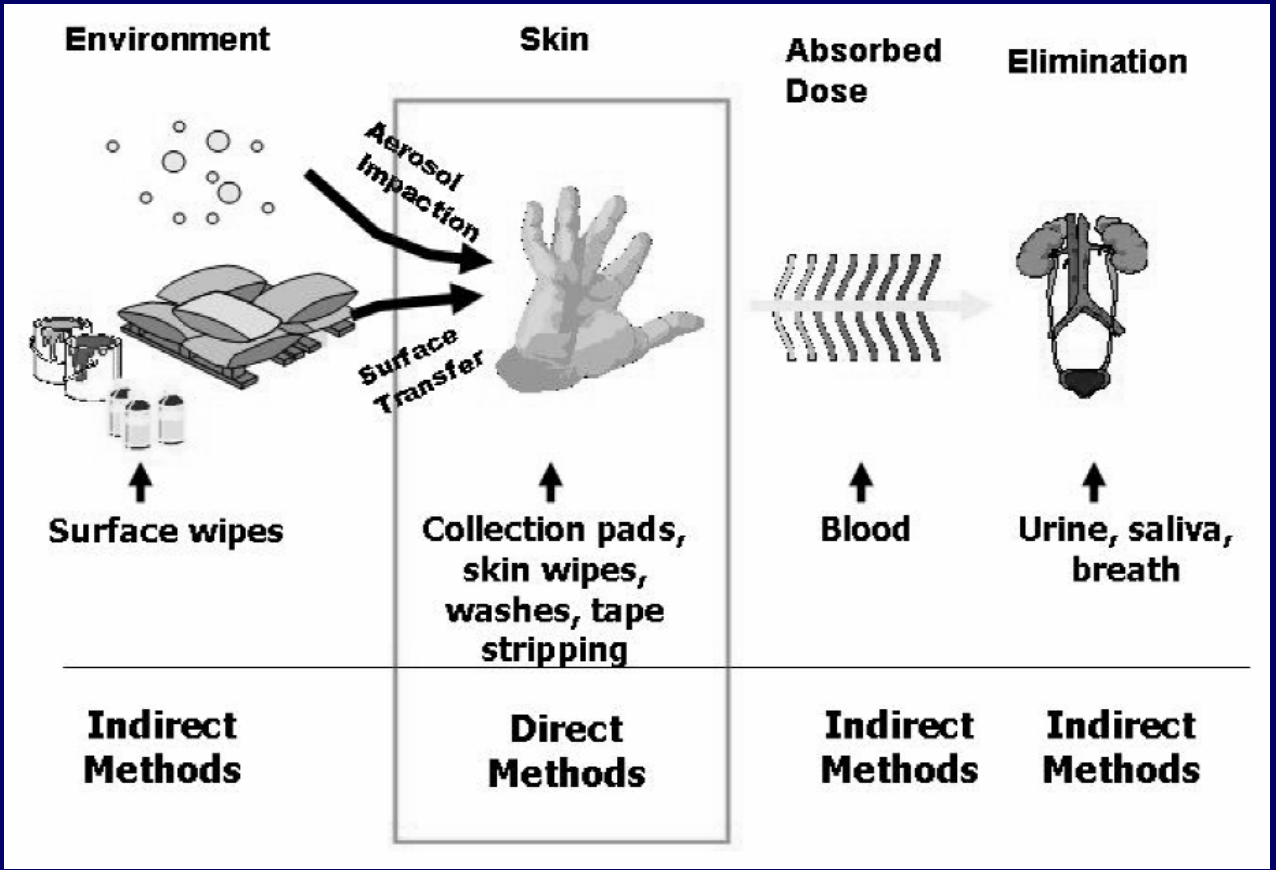
Total exposure rating = 288 (by 3 for hazard)

In the RED or very high priority category for exposure.

Further Information Gathering Semi-Quantitative Approaches

- Qualitative assessment approaches are good for screening but may be insufficient
- Next option is Step 4 – Further Information Gathering
  - Modeling of exposure and/or skin penetration
  - Indirect skin sampling methods
  - Direct skin sampling methods

Dermal Exposure Sampling



Dermal Monitoring: Indirect Methods

- Surface sampling: some standards exist, or can be used qualitatively to determine risk for skin exposure
  - Wipe samples
  - Vacuum samples
  - Colorimetric indicators (aromatic and aliphatic amines, isocyanates, lead, nickel, cadmium, beryllium)

Dermal Monitoring: Indirect Methods

- Biological Monitoring: indication of dermal as well as total body exposure dose
  - Chemical biomarkers (evidence or presence of a chemical in the body)
  - Effect biomarkers (biological or clinical change related to chemical exposure)
- BEIs and BEELs exist to evaluate results
- AIHA's Biological Monitoring Guidelines are available to help develop a program

Dermal Monitoring: Direct Methods

- Interception methods: collection of a contaminant on top of skin or clothing
  - Cotton gauze
  - PUF
  - Ghost wipes
  - Charcoal cloth
- Collection ability and retention must be compared with the skin – may over or under estimate

Dermal Monitoring: Direct Methods

- Removal methods:
  - Washing of skin
  - Wiping of skin
  - Adhesive tape stripping
- Removal will typically be incomplete – method differences, migration of contaminant into the skin
- Timing is important – before contaminant is absorbed into skin but not too early to miss some exposure; not effective for volatiles

Dermal Monitoring: Direct Methods

- In situ Methods: qualitative or quantitative evaluation of actual skin contamination
  - Fluorescent tracers
  - FTIR
  - X-ray fluorescence spectrometry
- Digital imaging software can be used to quantify exposures using fluorescence
- Great training tool for workers
- Helpful to determine whole body exposures – hands, arms, face, torso, etc.

Step 4
Further Information Gathering

- An exposure rating scheme for semi-quantitative or quantitative data

Rating	Description
1	Exposure <10% of BEI, BEEL or dermal OEL dose equivalent
2	Exposure 10-50% of BEI, BEEL or dermal OEL dose equivalent
3	Exposure 50-100% of BEI, BEEL or dermal OEL dose equivalent
4	Exposure >100% of BEI, BEEL or dermal OEL dose equivalent

What if you have sampling data?

- Skin surface or biological monitoring data can be evaluated using a mass equivalent of the OEL

  OEL (mg/m^3) x 10 m^3 air inhaled/day = mg/day

- Example: Lead on the surface of hands may be absorbed via ingestion in potentially hazardous amounts
- Lead has a TLV/PEL of 50 $\mu g/m^3$

  50 $\mu g/m^3$ x 10 m^3 = 500 µg/shift

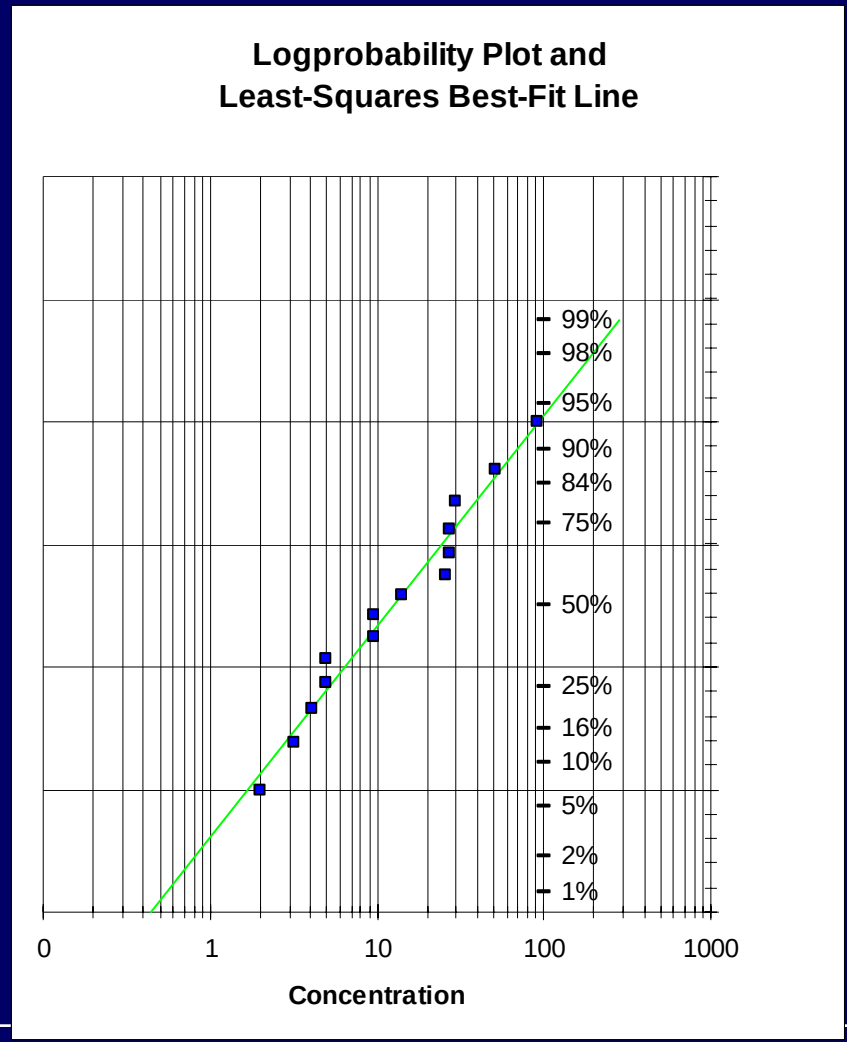
What if you have sampling data?

- Example: Consider an SEG of metal cutting employees who may be exposed to surface paints, oils, hydraulic fluids on scrap metal parts
- 14 skin surface samples for lead were taken of the whole hands (840 cm^2)
- Dermal sampling data is typically lognormally distributed
- Use IHSTAT for statistical analysis

NIOSH Health Hazard Evaluation Report. OmniSource Corp., Lima, OH. HETA #2003-0367-2973, July 2005.

IHSTAT Analysis of Dermal Data

- Confirmed that sample set was lognormally distributed
- GM = 12.5 µg
- SD = 3.2
- 95th percentile = 80.9 µg
- UTL = 243.5 µg
- 0.06% of samples above OEL



Statistical Analysis of Dermal Data

- Although OEL not likely to be exceeded through hand exposure alone, it could contribute up to 20% of the OEL allowable dose (using the 95th percentile value conservatively, which was close to 100 µg)
- This could be especially important if air exposures or other exposures are present
- Using the dermal quantitative exposure ranking, this task would most likely be rated a “2” (10-50% of OEL) – hazard is rated a “4”

IH Data Analyst - Freeware Version beta 1.0

File Edit View Conversions Calculate Graphs Options Help

Calculate All

Data | Initial Rating

Facility Information

Facility:
Department:
Building:
Process: Metal Recycling Facility
Task: Metal cutting

Substance Information

Substance: lead
OEL: 500 ug/m^3

Comments: Workers in SEG are cutting metals with surface paints, and contamination with oils and hydraulic fluids on scrap metal parts

Data Entry

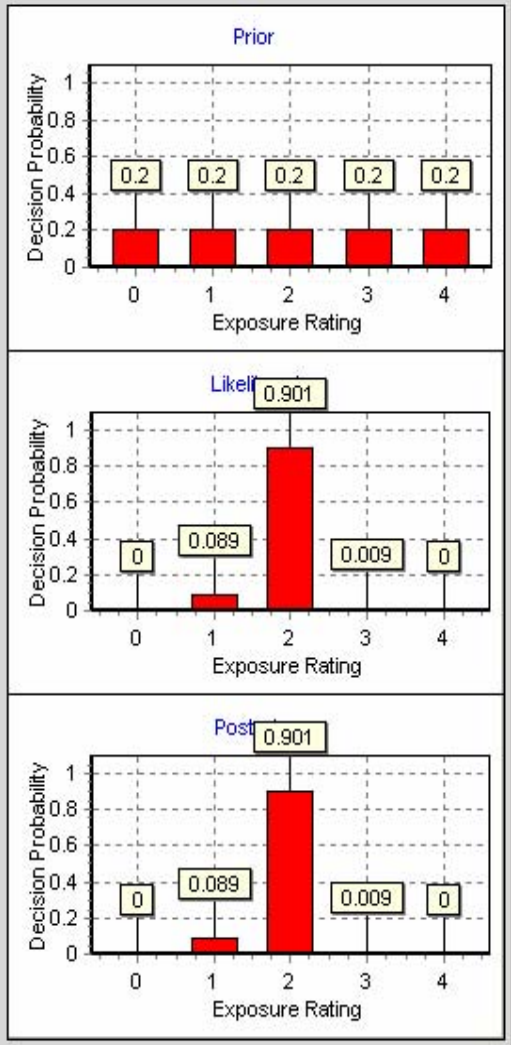
	CASE	CONC	<LOD	DATE	GROUP
3		4.9			
4		9.6			
5		3.2			
6		2			
7		4.9			
8		92			
9		30			
10		27			
11		51			

Statistics | Decision Charts

Decision Charts

Show all charts?
Yes
No

Bars and Labels
Solid bars
Solid bars with labels
Colored bars



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Calculate All

Data | Initial Rating

Facility Information

Facility:
Department:
Building:
Process: Metal Recycling Facility
Task: Metal Cutting

Substance Information

Substance: lead
OEL: 50 ug/m^3

Comments: Airborne exposures to lead

Data Entry

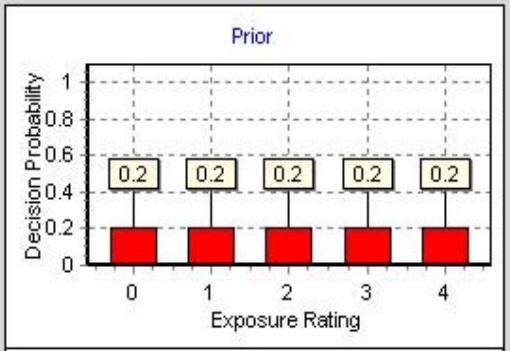
	CASE	CONC	<LOD	DATE	GROUP
1		7.9			
2		10.5			
3		7.9			
4		29.7			
5		31.5			
6		8.02			
7		4.34			
8		19.4			
9		27			
10		6.56			

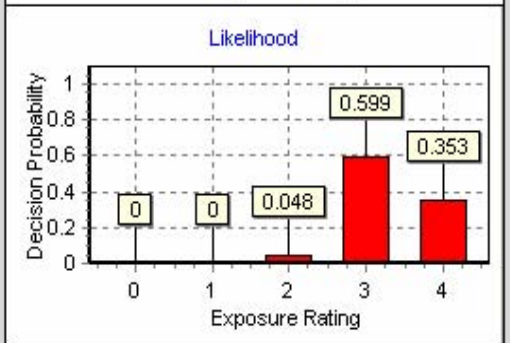
Statistics | Decision Charts

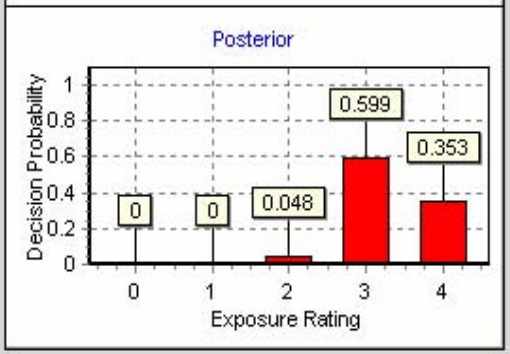
Decision Charts

Show all charts?
- Yes
- No

Bars and Labels
- Solid bars
- Solid bars with labels
- Colored bars







Summary
Dermal Risk Assessment

- Seek a balance between estimation, measurement, and management
- When measurement exposure values are not available, use an organized assessment approach to prioritize and classify exposures
- As always, apply the IH hierarchy of controls (i.e., use engineering controls before gloves whenever possible)